

AUSTRALIAN SEA STARS OF THE GENUS *PATIRIELLA*
(ASTEROIDEA, ASTERINIDAE)

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(Plates III, IV)

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Synopsis

Including the two new species described in this paper ten species of *Patiriella* are known from Australia. The Lamarckian species *Patiriella exigua* is shown to contain a tropical and temperate species. A neotype is erected to validate the identity of *P. exigua sensu stricto*. A key to the Australian species of *Patiriella* is provided. An account of the biogeography of the genus in relation to known marine zoogeographic boundaries is given.

INTRODUCTION

The present paper deals with asterinid sea stars of the genus *Patiriella* from Australia. *Patiriella* comprises a group of sea stars whose members are a conspicuous feature of the intertidal fauna of temperate and cool temperate shores in the Southern Hemisphere. Although the primary concern here is the fauna of Australia, some reference is also made to the asterinid faunas of South Africa, the Indo-west-Pacific area and New Zealand.

Australia and Tasmania possess eight species of *Patiriella* and two further species are described in this paper. *Patiriella exigua* (Lamarck) is common to South Africa and Australia and a New Zealand species (*Patiriella regularis* (Verrill)) is known as an introduced member of the Tasmanian marine fauna (Dartnall, 1969a).

Abbreviations used in the text are as follows: A.M., Australian Museum, Sydney; B.M., British Museum (Natural History), London; M.C.Z., Museum of Comparative Zoology, Harvard; M.N., Museum für Naturkunde, Berlin; N.M.V., National Museum of Victoria, Melbourne; Q.M., Queensland Museum, Brisbane; T.M., Tasmanian Museum, Hobart; U.S.N.M., United States National Museum, Washington, D.C.; W.A.M., Western Australian Museum, Perth. The material quoted is housed in the institution indicated by the initial preceding the registration numbers given. The number of specimens in each lot is indicated in parentheses after the registration number.

R is the greater radius of the specimen measured along the ambulacral groove; r is the lesser, interambulacral radius. Body proportions are expressed as a ratio $R:r$ and the height of the body is given as vh .

SYSTEMATIC ACCOUNT

Genus *PATIRIELLA* Verrill 1913

Type Species: *Asterina (Asteriscus) regularis* Verrill, 1867.

Asterinid sea stars with a plane actinal surface, short rays and a body outline varying from a blunt star to nearly pentagonal. Actinal intermediate spines rarely more than two, most often paired or single. Oral plates may carry one, two or no suboral spines. The inferomarginal plates and their spines form a fringing edge to the body and the superomarginal plates are not distinct. Abactinal spines are short, granular and bluntly capitate. The carinal row of

abactinal plates is doubly notched to accommodate two rows of papulae. Papulae are confined to the abactinal surface, along the rays, on the centre of the disc and the interradial, abactinal areas near the disc centre. The plates of the sides of the rays and the outermost interradial areas are apapulate. Pedicellariae are absent.

Species of this genus are found on rocky shores in the intertidal zone of southern and eastern Australia. Populations of some species may be found on mud, sand or gravel and can be taken below tidemarks to about 15 metres and occasionally at greater depths.

The genus *Patiriella* is most closely related to the predominantly northern hemisphere genus *Patiria*; to *Paranepanthia* which contains three nominal species in Australia, and to part of the heterogeneous genus *Asterina* from which *Patiriella* was originally removed.

In a previous account (Dartnall, 1970*b*) the genus was subdivided into "exigua", "regularis" and "gunni" groups. There are distinct morphological differences between these groups; within them are species of very similar morphology whose isolation is geographic, ecological or reproductive. In the following account the groups concerned are defined first, and thus the descriptions of species offered are concise, depending more on evidence of species isolation than indefinite morphological differences.

(a) "exigua" group

Small species of *Patiriella* in which *R* rarely exceeds 15 mm. The number of rays is usually five and actinal intermediate spines are usually single. Abactinal spines from the centre of the disc are from 0.2 to 0.3 mm. in length.

Patiriella exigua (Lamarck, 1816)

(Plate IV (c))

Restricted synonymy: *Asterias exigua* Lamarck, 1816; *Asterina krausii* Gray, 1840; *Asteriscus pentagonus* Müller and Troschel, 1842 (in part); *Asterina exigua* Perrier, 1876; *Patiriella exigua* Verrill, 1913 (in part); *Asterina exigua* Mortensen, 1921; *Patiriella exigua* H. L. Clark, 1938, 1946 (in part); Eudean, 1956 (in part); Shepherd, 1968; Dartnall, 1970*b*.

Non: *Asteriscus pentagonus* Müller and Troschel, 1842 (in part); *Asterina exigua* H. L. Clark, 1908; Koehler, 1910; Fisher, 1919; H. L. Clark, 1921; *Patiriella exigua* Livingstone, 1932; *Asterina (Patiriella) exigua* Mortensen, 1933*a*; Domantay and Roxas, 1938; Engel, 1938.

Asterina minuta of various authors has not been included in the synonymy because of lack of precise information about localities. However, Gray (1840) was clear that the specimens he attributed to *A. minuta* were from the "West Indies, St. Vincents". If those details are correct then those specimens are probably Lütken's *Asterina folium* or a related form. Information about *A. folium* with which to compare Gray's *A. minuta* is available in a paper by de Roa (1967). As far as synonymy is concerned the complex of asterinids from South Africa has also been ignored in this paper as it is commented upon by both H. L. Clark (1923) and Mortensen (1933*a*).

Asterias exigua Lamarck was described from material whose provenance was suggested to be the Americas (Perrier, 1876). Perrier examined Lamarck's seven type specimens and also noted that a further series of nine specimens, collected from the Cape of Good Hope in 1829 by M. Raynaud, were labelled *Asterias exigua* by Lamarck. Perrier (*loc. cit.*) and Koehler (1910) both recognized *Asterias exigua* as a valid species containing the synonyms *Asterias minuta* de Blainville, 1834; Agassiz, 1834 (in Agassiz, 1838) and Gray, 1840; *Asteriscus pentagonus* Müller and Troschel, 1842 and *Asterina pentagona* von Martens, 1866.

Patiriella exigua is recorded in the literature from throughout the Australo-Indo-west-Pacific from South Africa to the Philippines, the New Hebrides and the eastern and southern coasts of Australia including Tasmania. Whitelegge (1889) was the first to note the orally directed gonoducts of the adult and the shortened development of the larvae. Mortensen (1921) confirmed Whitelegge's observations and suggested that *P. exigua* might contain more than one species, quoting Ludwig that *Asterina pentagona*, an accepted synonym, possessed genital pores opening on the abactinal surface. Since that time abbreviated development has been accepted as characteristic of the species and an account is incorporated in at least one standard textbook of zoology (Parker and Haswell, 1962).

In September, 1967, Dr. J. R. Grindley obtained for me material attributed to *Patiriella exigua* from Port Elizabeth, South Africa. This material can be divided into two groups:

(1) Asterinid sea stars with abactinally directed gonoducts, attaining 18 mm. *R* in these samples and whose actinal surface is not consistently blue-green in colour. Miss A. M. Clark of the British Museum (Natural History) was kind enough to compare some of these specimens with material in her care and informs me that they agree best with *Asterina dyscrita* H. L. Clark, 1923.

(2) Asterinids with actinally directed gonoducts, attaining a maximum *R* of approximately 12 mm. and whose actinal surface is always blue-green in colour.

The latter group is identical to that species of sea star from south-eastern Australia commonly determined as *Patiriella exigua* and it was decided to investigate that species throughout its known range. Through the co-operation of many individuals and institutions, material was obtained from areas throughout most of the recorded distribution of the species and all the specimens were examined to determine the position of the gonopores and the orientation of the gonoducts. Morphological differences between the samples were slight and gonopore position remained the one constant character for investigation in preserved material. The map (Fig. 1) shows the localities from which material was obtained. Orientation of gonoducts in the samples is indicated by the arrowheads and the following distribution is clear.

North of about 28° S. in Australia all the samples attributed to *Patiriella exigua* possessed abactinally orientated gonopores.

In Australia the form with actinally directed gonopores is found along the east coast, south of approximately 28° S., to Port Lincoln on the south coast at approximately 136° E. The range of this form extends southwards to encompass the coasts of Tasmania and eastward of the continent to Lord Howe Island at about 159° E. This form is also found in South Africa and the isolated islands of St. Paul and New Amsterdam.

Application to Dr. G. Cherbonnier revealed that Lamarck's types of *Asterias exigua* are no longer in Paris. Dr. E. Binder of Geneva and Dr. W. Vervoort of Leiden inform me that neither of their institutions hold Lamarckian echinoderm types. Further enquiries suggest that Lamarck's specimens no longer exist and in order to preserve the name "*exigua*" for this well-documented animal it appears necessary to erect a neotype for the species.

The Cape of Good Hope has been accepted as the type locality by various authors, but without a locality for Lamarck's specimens this is very uncertain. Among those specimens available to me the two from the Cape do not demonstrate adequately the key character to the species, namely the gonopores, so I have chosen a recent specimen from False Bay, South Africa, which lies to the east of the Cape of Good Hope and is now designated the type locality.

Details of neotype: T.M. H508. $R=11.5$ mm., from the type locality, False Bay, South Africa (34° S./ 18° E.); 10.x.1969; don. J. G. Field.

Other material examined:

A.M. J7762 (6), City of Melbourne Bay, King Is., Tasmania, June 1968, S. Kerrison.

B.M. 1840.11.25.1 and 1840.11.25.5, Cape of Good Hope. Both specimens are syntypes of *Asterina kraussii* Gray.

M.N. 6682 (35), St. Paul Island, 26.iv.1903, Deutsche Südpolar-Expedition 1901-1903; 6683 (6), Amsterdam Is., 27.iv.1903, Deutsche Südpolar-Expedition.

N.M.V. H151 (6), Flinders, Victoria, 6.vi.1969, A. J. and P. J. Darnall.

Q.M. G3765 (4), Currumbin, Queensland, 8.viii.1953, R. Endean.

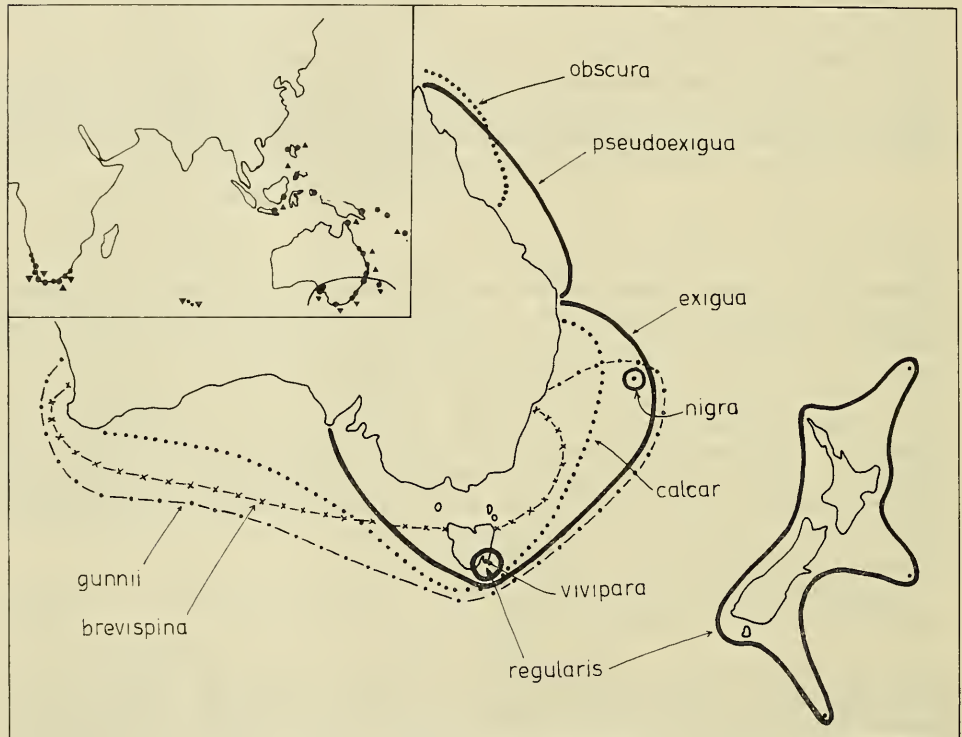


Fig. 1. Contemporary distribution of the species of *Patiriella* found in Australia. *P. inornata* from Western Australia is omitted.

Inset: Map showing the localities from which material of the "exigua" group has been obtained. Orientation of gonopores is shown by the solid triangles—▲ abactinal: ▼ actinal.

T.M. H212 (2), Roaring Beach, Port Davey, Tas., Feb. 1937, C. Davies; H222 (12), Stanley, Tas., Oct. 1937, A. W. G. Powell; H332 (31), Nubeena, Tas., 14.v.1967, L. Jenkins; H345 (2), Murdunna, Tas., 12.i.1967, A. J. Darnall; H349 (8), Port Arthur, Tas., 20.iv.1967, A. P. Andrews and E. Aves; H365 (12), Granville Harbour, Tas., 6.xi.1967, A. J. Darnall; H392 (6), Dennes Pt., Bruny Is., Tas., 24.i.1968, A. J. Darnall; H409 (13), South Australia, 1967, S. A. Shepherd; H452 (4), Maria Is., Tas., 15.iv.1968, A. J. Darnall; H456 (4), Swan Is., Tas., Sept. 1968, F. L. Sutherland; H458 (9), Cape Portland, Tas., 2.iii.1969, A. J. Darnall; H479 (18), Salmon Reef, Lord Howe Is., 6.xi.1968, W. G. Thornton; H480 (6), Trouser's Point, Flinders Is., Tas., 7.i.1969, T.

Goede; H483 (7), Marawah, Tas., 1.xii.1968, B. J. Smith; H484 (5), Greens Beach, north Tas., 13.viii.1969, R. H. Green; H485 (10), Stevens Bay, Port Davey, Tas., 8.i.1969, D. Milledge; H486 (10), Long Reef, near Sydney, N.S.W., 1.viii.1969, E. C. Pope; H496 (5), Salt Creek, Port Lincoln, S. Australia, 10.xi.1969, J. Veitch; H494 (6), Port Elizabeth, South Africa, Sept. 1967, J. R. Grindley; H498 (8), False Bay, South Africa, 34° S./18° E., 10.x.1969, J. G. Field.

UNIVERSITY OF CAPE TOWN: ECOLOGICAL SURVEY COLLECTIONS. All from South Africa. L10 (8), East London, 32° S./28° E., 6.vii.1937; LB112 (4), Langebaan Lagoon, 33° S./18° E., 15.vii.1946; N35 (6), Port Nolloth, 29° S./16° E., 27.x.1935; LU3A (13), Luderitz, 26° S./15° E., 15.vii.1946; D24 (8), Durban, 29° S./15° E., 27.vi.1935; A7 (10), Oudekraal, 34° S./18° E., 2.i.1934; E3 (9), Port Elizabeth, 33° S./28° E., 3.vii.1936; S9 (10), Still Bay, 34° S./21° E., 4.i.1932.

W.A.M. 37-69 (1), Sydney, N.S.W., late 1963, C.S.I.R.O. Fisheries; 39-69 (3), Gunnamatta Bay, Port Hacking, N.S.W., 31.x.1963, C.S.I.R.O. Fisheries.

Description: As above, in the description of "*exigua*" group. Oral spines 5-6; suboral spines 1; furrow spines 2 to each adambulacral ossicle and basally webbed; subambulacral spines 1. Actinal intermediate spines 1, 2 towards the disc margin, absent proximal to the mouth plates. In preserved specimens the plate at the apex of the chevron which defines the actinal intermediate area may "float" clear of its fellows on a sheet of membrane. A pair of gonopores are present in each actinal intermediate area about level with the third ambulacral ossicle and between the second and third chevrons of actinal intermediate plates (Plate IV, c).

R: *r* about 1.2-1.3:1.

Diagnosis: A small species of *Patiriella* with actinally directed gonoducts and abbreviated larval development.

Colour in life: The actinal surface is consistently blue-green. The ground colour of the abactinal surface is dull green or brown. Red, orange, purple, brown or pastel greens or browns on the spines grouped at the inferomarginal fringe, along the top of the rays and at the disc centre, often produce an attractive geometric pattern against the ground colour. The tissues of the circum-oral ring are blue-green. The tube feet are blue-green and the suckers off-white. The papulae are transparent, showing blue-green coloration at their exit from the papular pores.

Distribution: South Africa, St. Paul group, Australia south of 28° S. and E. of 136° E., Tasmania, Lord Howe Island.

Habitat: Mid-tide level on rocky shores. In areas where wave splash is consistent the species may be found high on the shore. Specimens from South Australia were taken under rocks on a muddy substrate and the species has been collected on sand at Anson's Bay, N.E. Tasmania. In Australia *Patiriella exigua* is often associated with the alga *Hormosira banksii*.

Patiriella pseudoexigua sp. nov.

(Plate IV (a))

Synonymy: ? *Asteriscus pentagonus* Müller and Troschel, 1842 (in part), ? *Asterina pentagona* von Martens, 1866; *Asterina exigua* H. L. Clark, 1908; ? Koehler, 1910; *Patiriella exigua* Verrill, 1913 (in part); *Asterina exigua* Fisher, 1919; *Asterina exigua* H. L. Clark, 1921; *Patiriella exigua* H. L. Clark, 1938 (in part); ? *Asterina (Patiriella) exigua* Domantay and Roxas, 1938; Engel, 1938; *Patiriella exigua* H. L. Clark, 1946 (in part); Endean, 1956 (in part).

Ludwig (*in* Mortensen, 1921) observed that *Asterina pentagona* von Martens possessed genital pores opening on the abactinal surface of the animal in contrast to *Patiriella exigua*. Thus it would appear that the name *pentagonus* of Müller and Troschel is available to accommodate the species of *Patiriella* found north of 28° S. in Australia. However, two species of *Patiriella* are present in north-eastern Australia and I find it impossible to decide which is actually *pentagonus* of past authors. Accordingly both this species and one belonging to the "regularis" group are described as new. Future workers in the Indo-west-Pacific may need to place one of these species in synonymy if further information validates the status of Müller and Troschel's species name. The alternative is to declare formally that *pentagonus* is invalid, but this must await further studies on the species of *Patiriella* in the waters north of Australia.

Holotype: T.M. H499. A dried specimen, $R=12.5$ mm., Airlies Beach, Proserpine, Queensland (type locality), 12.iv.1970, A. J. Dartnall.

Paratypes: T.M. H500 (6), Airlies Beach, Proserpine, Queensland, 12.iv.1970, A. J. Dartnall; A.M. J7761 (2), Airlies Beach, Queensland, September/October 1968, K. Deacon.

Other material examined:

B.M. 1890.5.7.581-584 (4), Zamboanga, Philippines; 1968.6.14.156-160 (5), Solomon Islands.

M.C.Z. 2297 (1), Murray Is., Mer., Oct. 1913, H. L. Clark, Carnegie Expedition; 2083 (15), Espiritu Santo, Malo, New Hebrides, January 1911, Rev. J. Annand; 2296 (23), Erub, Torres Strait, 19.ix.1913, H. L. Clark; 2298 (1), Erub, Torres Strait, 19.ix.1913, H. L. Clark.

N.M.V. H116 (1), Aola, Guadalcanal, 1901, G. Officer; G114 (1), Bora Bada, New Guinea, March 1891, J. Exton; H110 (1), Bingal Bay, Queensland, July 1964, J. Kerslake.

Q.M. G3767 (2), Port Curtis, Queensland, 16.viii.1961, R. Endean; G3762 (26), South Yeppoon, Queensland, 15.i.1953, R. Endean; G3764 (22), Airlies Landing, Proserpine, Queensland, 21.iv.1953, R. Endean.

T.M. H501 (32), Airlies Beach, Proserpine, Queensland, 12.iv.1970, A. J. Dartnall; H502 (4), one mile N.E. Airlies Beach, Proserpine, Queensland, 12.iv.1970, A. J. Dartnall; H503 (6), south end of King's Beach, Bowen, Queensland, 13.iv.1970, A. J. Dartnall.

U.S.N.M. 38088 (12), Philippine Islands, E. A. Mearns; 40261 (7), Port Binang, Subic Bay, Philippines, 8.i.1908, Albatross Philippines Expedition 1907-1910; 40254 (4), Borneo, 2.iii.1908, Albatross Expedition.

W.A.M. 43-69 (3), Real Point, Villa Carmen, Cabcaben, Bataan, Philippines, 24.vii.1965, Western Australian Museum Luzon Expedition 1965.

Description of holotype: A small asterioid sea star very similar in morphology to *Patiriella exigua*. $R:r$ about 1.3:1. Rays five. Each oral plate with five oral spines and one suboral spine. Most furrow spines are paired except near the mouth plates, where two or three adambulacral plates carry three furrow spines. The subambulacral and actinal intermediate spines are each placed singly on an actinal plate. There are no pairs of spines towards the edge of the disc and spines are absent near to the mouth plates. The inferomarginal plates carry seven to nine spines; the abactinal plates four to 20 spinelets.

The gonoducts are orientated abactinally and the gonopores open on the abactinal surface.

Diagnosis: A small species of *Patiriella* with abactinally directed gonoducts.

Colour in life: The actinal surface is a dull brownish-green; the abactinal surface dull brown and green. Most specimens are darker on the centre of the disc and along the crest of the rays, forming a five-rayed star pattern on the

abactinal surface. Variants show some russet and orange patches in the inter-radial areas. The circum-oral ring is bluish, the tube feet pale straw coloured, and the suckers off-white.

Distribution: The east coast of Australia north of about 28° S., Torres Strait, New Guinea, the New Hebrides, the Philippines and Borneo.

Habitat: Under rocks at mid-tide level.

Patiriella vivipara Dartnall, 1969

Diagnosis: A small species of *Patiriella* with no gonoducts; coelomic incubation of young; viviparous.

Distribution: Restricted to S.E. Tasmania.

(b) "regularis" group

Species of *Patiriella* resembling the "exigua" group morphologically, in which *R* exceeds 15 mm. and the abactinal spinelets are longer than in the "exigua" group (between 0.4 and 0.9 mm. in length).

Patiriella regularis (Verrill, 1867)

Restricted synonymy: *Asterina* (*Asteriscus*) *regularis* Verrill, 1867; *Patiriella regularis* Verrill, 1913; *Patiriella mimica* Livingstone, 1933; *Patiriella regularis* Dartnall, 1970.

Diagnosis: A species of *Patiriella* with five rays. $R:r=1.5-1.8:1$.

Distribution: New Zealand and S.E. Tasmania.

Patiriella inornata Livingstone, 1933

Diagnosis: A species of *Patiriella* with five rays, short furrow spines and the innermost oral spine notched at the tip.

Distribution: Western Australia.

Remarks: This species is known only from the holotype.

Patiriella nigra H. L. Clark, 1938

Diagnosis: Five rays. Actinal intermediate area with dense spinulation; many plates towards the inferomarginal fringe carrying two or three spines. On the abactinal surface the spinulation of the papulate areas is distinct, approaching the condition described for species of *Paranepanthia*. Colour in life black. The gonopores open on the abactinal surface.

Distribution: Lord Howe Island.

Patiriella obscura sp. nov.

(Plate IV (b))

Synonymy: ? *Patiriella exigua* Livingstone, 1932; *Patiriella exigua* Endean, 1956 (in part).

Museum samples showed that a large species of *Patiriella* was present in north-eastern Australia and probably extended to the Philippines. When I first collected this animal alive I considered it to be the adult of *Patiriella pseudoexigua* sp. nov. However, examination showed that the gonads of *P. obscura* were not mature until 13 mm. *R* was attained and *P. pseudoexigua* possesses mature gonads at 11 mm. *R*.

Holotype: T.M. H504. A dried specimen, *R*=18 mm., Rose Bay, Bowen, Queensland (type locality), 13.iv.1970, A. J. Dartnall.

Paratypes: T.M. H505 (6) and A.M. J7791 (6), Rose Bay, Bowen, Queensland, 13.iv.1970, A. J. Dartnall.

Other material examined:

Q.M. G5330 (2), Rowe's Bay, Townsville, Queensland, August 1967, R. Monroe; G3763 (5), Low Island, Queensland, 13.viii.1954, R. Endean.

T.M. H506 (15), Rose Bay, Bowen, Queensland, 13.iv.1970, A. J. Darnall; H507 (23), Rowe's Bay, Townsville, Queensland, 14.iv.1970, A. J. Darnall.

COLL. ZOO. DEPT., UNIVERSITY OF THE PHILIPPINES. Two dried specimens from the vicinity of Port Galera Bay.

Description of holotype: A species of *Patiriella* with five rays. $R:r=1.2:1$. Each oral plate carries five or six oral spines and one or two suboral spines. Most furrow spines are arranged in pairs, but two adambulacral plates near the mouth carry three spines. Subambulacral spines are single with occasional pairs. Actinal intermediate spines are mainly single with occasional pairs near the edge of the disc. Fringing spinelets are in groups of seven to 13. The abactinal spinelets range from four to 20 to an abactinal plate.

The gonopores open on the abactinal surface.

Diagnosis: A species of *Patiriella* of $R > 15$ mm. with abactinally directed gonoducts. Suboral spines often paired.

Colour in life: The actinal surface is dull brownish-green; the abactinal surface dull brown, reddish and purple. Dull, pale colours show indistinct geometric patterns against the ground colour. Tube feet greenish-blue; suckers off-white. Circum-oral ring bluish.

Distribution: N.E. Australia to the Philippines.

Habitat: Under rocks at mid-tide level. This species will feed over the surface of mud surrounding rocks at low tide and the body colour provides very effective camouflage at this time.

Patiriella calcar (Lamarek, 1816)

Restricted synonymy: *Asterias calcar* Lamarek, 1816; *Asterina calcar* McCoy, 1890; *Patiriella calcar* Verrill, 1913; H. L. Clark, 1946; Endean, 1953; Shepherd, 1968; Darnall, 1970b.

Diagnosis: A species of *Patiriella* with seven to 11 rays, usually eight. Apart from the number of rays this species falls most naturally into the "*regularis*" group.

Distribution: From the south coast of Western Australia to southern Queensland and the coasts of Tasmania.

Remarks: It appears that Lamarek's types of *Asterias calcar* no longer exist. I have not erected a neotype for this species because I am not aware that the identity of this well marked species has been questioned.

(e) "*gunni*" group

Species of *Patiriella* with six rays and the spines of the actinal intermediate area arranged in pairs. Abactinal spines near centre of the disc between 0.2 and 0.4 mm. in length.

Patiriella gunnii (Gray, 1840)

Restricted synonymy: *Asterina gunnii* Gray, 1840; *Patiriella gunnii* Verrill, 1913; H. L. Clark, 1946; A. M. Clark, 1966; Shepherd, 1968; Darnall, 1970b.

Diagnosis: A flattened form with paired subambulacral spines. Maximum R about 39 mm.

Distribution: Known from Tasmania, Western Australia to New South Wales, Lord Howe Island.

Patiriella brevispina H. L. Clark, 1938

Diagnosis: An arched form with single subambulacral spines attaining about 52 mm. *R*.

Distribution: Western Australia to New South Wales, the north coast of Tasmania.

Key to the Australian Species of *Patiriella*

1. Actinal intermediate spines paired; rays six....." *gunnii* " group (2)
Actinal intermediate spines single; rays usually five or more than six.....(3)
2. (1) Flattened; subambulacral spines usually paired; Colour in life varied... *Patiriella gunnii*
Arched; subambulacral spines usually single; colour consistently and uniformly purple..... *Patiriella brevispina**
3. (1) Small; $R < 15$ mm., actinal spines < 0.4 mm. in length " *exigua* " group (4).
Large; $R > 15$ mm., actual spines > 0.4 mm. in length " *regularis* " group (6).
4. (3) Gonoduct absent; coelomic incubation of young..... *Patiriella vivipara*
Gonoduct present.....(5)
5. (4) Gonoducts directed actinally. Actinal surface blue-green..... *Patiriella exigua*
Gonoducts directed abactinally. Actinal surface dull brownish green *Patiriella pseudoexigua*
6. (3) Rays 7-11..... *Patiriella calcar*
Rays 5..... (7)
- 7 (6) Spination of apapulate and papulate abactinal areas distinct; colour black (Lord Howe Is.)..... *Patiriella nigra*
Spination of abactinal interradial areas not as dense as above; colour not black... ..(8)
8. (7) Innermost oral spine flat, very wide notched at tip..... *Patiriella inornata*
Innermost oral spine not as above..... (9)
9. (8) Suboral spines single; colour of actinal surface off-white..... *Patiriella regularis*
Suboral spines often paired; colour of actinal surface dull brownish-green *Patiriella obscura*

* In a previous key to the Asterinidae of Tasmania (*Proc. Roy. Soc. Tas.*, 1970) this section runs down to *P. calcar*. The opportunity is taken to rectify this mistake here.

DISCUSSION

The distribution of species within the " *exigua* " group shows a sequence in which each species is separated from the next by a reproductive mechanism. These observations reinforce the concept of sibling pairs of species mooted in a previous paper (Dartnall, 1970*b*) except that a triple sequence is now discernible. *Patiriella pseudoexigua*, with upwardly directed gonoducts and presumably free-swimming larvae, is found north of 28° S. in eastern Australia. South of 28° S. and isolated from *P. pseudoexigua* by a reproductive " inversion " is *Patiriella exigua*. The third species in the sequence is the hermaphrodite, viviparous form, *Patiriella vivipara*, which is restricted to the cool coasts of S.E. Tasmania.

The discovery of a " *regularis* " form (*Patiriella obscura*) in N.E. Australia adds weight to the concept that the precursors of *Patiriella* came from the Indo-west-Pacific area. It is suggested that the " *regularis* " forms have contributed to the New Zealand fauna (*Patiriella regularis*) by way of the Lord Howe Rise (*Patiriella nigra*) and to south-eastern Australia through evolution of *Patiriella calcar*. It is possible that the " *exigua* " forms represent an older invasion as the contemporary distribution of *P. exigua* encompasses the temperate and cool temperate waters of both Australia and South Africa and the intervening St. Paul group of islands (see Fig. 1).

Figure 1 shows the present distribution of the Australian species of *Patiriella*. The limits of distribution of *P. exigua* and *P. pseudoexigua* at about 28° S. roughly correspond with the biogeographic boundary defined amongst others by Eudean (1957) when he considered the biogeography of the shallow water echinoderm fauna of Queensland. When the distribution of the species belonging to the " *gunnii* " group is also considered it can be seen that the agreement with the marine zoogeographic provinces of Bennett and Pope (1953, 1956) is marked and that the distributional limits accord well with those postulated by George (1969) for the tropical and subtropical Palinuridae.

In an earlier paper (Dartnall, 1970a) the distributions of the hermaphrodite forms known within the Asterinidae were shown to lie in widely separate areas around 40° of latitude, both north and south. This evidence must now be restricted to the non-fissiparous asterinids because Dr. R. Kenny has sent me samples of hermaphrodite individuals of *Nepanthia belcheri* (Perrier) from Moreton Bay, Queensland. When the distribution of the species belonging to the "exigua" sequence is considered, the speculations which follow are of interest.

(a) The distributions of the "exigua" species are defined by thermal tolerance alone, the observed sequence of reproductive mechanisms being fortuitous.

(b) Each kind of reproductive mechanism is limited by temperature, higher latitudes and lower temperatures directing the success of hermaphrodite forms, species with abbreviated development, or a combination of both.

It is probably not possible to test these speculations. However, it may be possible to find out whether similar reproductive sequences occur in other groups of Asteroidea along the long eastern seaboard of Australia.

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